ORIGINAL RESEARCH

The Impact of Backboard Placement on Chest Compression Quality: A Mannequin Study

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Abbreviations:
ACLS: Advanced Cardiac Life Support
AHA: American Heart Association
BLS: Basic Life Support
CC: chest compression
CPR: cardiopulmonary resuscitation
EM: Emergency Medicine

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Abstract

Introduction: High-quality chest compressions (CCs) are associated with high survival rates and good neurological outcomes in cardiac arrest patients. The 2015 American Heart Association (AHA; Dallas, Texas USA) Guidelines for Resuscitation defined and recommended high-quality CCs during cardiopulmonary resuscitation (CPR). However, CPR providers struggle to achieve high-quality CCs. There is a debate about the use of backboards during CPR in literature. Some studies suggest backboards improve CC quality, whereas others suggest that backboards can cause delays. This is the first study to evaluate all three components of high-quality CCs: compression depth, recoil depth, and rate, at the same time with a high number of subjects. This study evaluated the impact of backboards on CC quality during CPR. The primary outcome was the difference in successful CC rates between two groups.

Methods: This was a randomized, controlled, single-blinded study using a high-fidelity mannequin. The successful CC rates, means CC depths, recoil depths, and rates achieved by 6th-grade undergraduate medical students during two minutes of CPR were compared between two randomized groups: an experimental group (backboard present) and a control group (no backboard).

Results: Fifty-one of all 101 subjects (50.5%) were female, and the mean age was 23.9 (SD = 1.01) years. The number and the proportion of successful CCs were significantly higher in the experimental group (34; 66.7%) when compared to the control group (19; 38.0%; P = .0041). The difference in mean values of CC depth, recoil depth, and CC rate was significantly higher in the experiment group.

Conclusion: The results suggest that using a backboard during CPR improves the quality of CCs in accordance with the 2015 AHA Guidelines.

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Introduction

Cardiopulmonary resuscitation (CPR) is a commonly used medical procedure developed by Safar and Kouwenhoven in mid-20th century.[1] Chest compressions (CCs) are vital components of CPR, and high-quality CCs are related to high survival rates and good neurological outcomes.[2–4] The updated 2015 American Heart Association (AHA; Dallas, Texas USA) Guidelines for CPR describes high-quality CCs as the CCs with adequate depth, full recoils, and adequate rate with minimal interruptions.[5,6] Studies with simulated and real cardiac arrest cases have shown that, despite CPR training and its widespread use, CC providers struggle to achieve high-quality CCs and the post-CPR survival rates remain low.[2,7–10]

Many studies focused on this problem and aimed to identify the factors influencing the CC quality. The support surface is one of these factors. Mattresses move downwards with the compression, increasing the distance of the vertical movement and fatigability of the provider during CPR. The increased workload and fatigability cause insufficient compression depth, recoil, and rate.[11,12] Recent studies have shown that performing CPR on mattresses reduces CC quality.[9,12–14]

In theory, backboard placement between the patient and the mattress should provide a firm and stable surface, should decrease the compliance of the underlying mattress by increasing the surface area of the applied force, and should decrease the distance of the vertical hand movement. These factors cause reduced workload and increased CC quality.[15,16] The AHA Guidelines suggest an optional use of backboards, due to the considerably active debate in the literature and lacking evidence for using backboards during CPR.[2,17–19] Some past studies stated that backboard placement improves the CC quality during CPR,[15,17,20,21] others suggested against the use of backboards since unnecessary delays may occur.[17,22]

Past studies that evaluated the impact of backboards mostly focused on the compression depth component of CC. However, the quality of CCs relies on compression depth, recoil, and rate altogether. There are no studies in the literature that evaluated the effects of backboard placement on all three components of CC during CPR.

This randomized, controlled study aimed to evaluate the impact of backboard placement on CC quality by assessing all three components of CC: compression depth, recoil depth, and compression rate.

Methods

The study protocol was approved by the Institutional Review Board (IRB) of the Marmara University Pendik Education and Research Hospital, Istanbul, Turkey (IRB No: 09.2017.575). Written informed consent was obtained from every student who participated in this study. All procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation, and also with the Helsinki Declaration of 1975, as revised in 2008.

Study Setting

This prospective, randomized, controlled, single-blinded study was conducted from October 2017 through March 2018 at a simulation center. This 800 square meter simulation center with four simulation areas, camera systems in simulation areas, and a brief-debrief room consisted of two high-fidelity and six low-fidelity mannequins. All simulations were performed on the SimMan Essential (Laerdal; Stavanger, Norway) high-fidelity mannequin, which was suitable for Basic Life Support (BLS), Advanced Cardiac Life Support (ACLS), and Advanced Trauma Life Support (ATLS) training. The mannequin was placed on an eight centimeter foam mattress and an emergency department stretcher (Finex; ES OO-SL, Turkey) underneath the mattress.

Study Population and Design

The study population consisted of 6th-grade undergraduate medical students at Marmara University Faculty of Medicine. All students were provided with BLS and ACLS lessons, in accordance with the 2015 AHA Guidelines of CPR, during their two-month Emergency Medicine (EM) clerkship program prior to the study, as defined in the curriculum. After their EM clerkship, all subjects who agreed to participate in the study and signed an informed consent form were recruited for this study. Subjects with missing data (n = 2) and informed consent withdrawal (n = 3) were excluded. A total of 101 subjects were analyzed in the study (Figure 1). Subjects were randomized (Research Randomizer website; online tool offered by Social Psychology Network) into two groups: the experimental group (backboard placed between the mannequin and the mattress) and the control group (no backboard). In the experiment group, a backboard was placed between the mannequin and the mattress before each scenario. A black sheet (same color with the mattress) was used to cover the mattress and the backboard (if present) to maintain the blindness of the subjects. Neither group was informed about the use of backboards in the scenarios. All subjects were presented with a cardiac arrest scenario and performed two minutes of CCs. The software of the mannequin automatically recorded the mean CC depths, recoil depths, and rates. The quality of the CCs was expected to be in accordance with the updated 2015 AHA Guidelines of CPR. Two educators with BLS and ACLS certifications were present at all times during the management of the scenarios. Educators did not intervene with the scenario management process or guide the subjects. A video-assisted debriefing was performed after all evaluations for educational purposes.

Data Collection

All data regarding compression depth, recoil depth, and compression rate were recorded by the sensors of the mannequin and sent to a dedicated Laerdal Learning Application (LLEAP; Laerdal; Stavanger, Norway) server. The data were extracted from the server and then analyzed. Demographic data of the subjects were noted on a datasheet and transferred to the same datasheet.

Outcomes and Definitions

The primary outcome was defined as the difference in the proportion of successful CCs between the experiment and the control groups. The secondary outcomes were defined as the difference in mean CC depths, recoil depths, and rates between the two groups. Adequate CC depth was accepted to be 50mm to 60mm, an adequate CC recoil depth was accepted to be 50mm to 60mm, and an adequate CC rate was accepted to be 100bpm to 120bpm in accordance with the updated 2015 AHA Guidelines of CPR. A successful CC was announced if requirements for all three components of CCs were met.

Statistical Analysis

Continuous variables were reported as means and standard deviations (SD) with 95% confidence intervals (CI). The normality of the distribution of the continuous variables were tested with The Kolmogorov-Smirnov test. The significance of the difference between independent groups was assessed by Student's t test. Categorical variables were compared by Fisher's exact test and reported as rates and counts. MedCalc Statistical Software version 17.9.7 (MedCalc Software bvba; Ostend, Belgium; 2017) was used for statistical analysis. A P value of <.05 was considered as significant. The 2010 CONSORT Statement was used as a reference while preparing for this report.[23]

Results

In this study, 101 subjects were randomized into two groups: experimental group (n = 51) and control group (n = 50). Fifty-one of all 101 subjects (50.5%) were female, and the mean age was 23.9 (SD = 1.01) years. Both groups were similar with regard to baseline demographic characteristics (Table 1). The mean values (SD) of compression depth and recoil depth of the experiment group (50.1 [SD = 4.8]; 49.2 [SD = 5.0]) were significantly higher than the control group (47.5 [SD = 4.7]; 46.0 [SD = 4.7]; P = .006 and P = .001, respectively). The mean compression rate of the experiment group was also significantly higher than the control group (103.5 [SD = 10.6]; 97.8 [SD = 9.7]; P = .007, respectively). The number and the proportion of successful CCs were significantly higher in the experimental group (34; 66.7%) when compared to the control group (19; 38.0%; P = .004; Table 1). The CC success rates, CC depths, CC recoil depths, and CC rates of individual subjects of both groups are presented in Figure 2, Figure 3, Figure 4, and Figure 5, respectively.

Discussion

In this study, the impact of backboards on three components of CCs (CC depth, CC recoil depth, and CC rate) were evaluated during CPR on a high-fidelity mannequin.

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Variable	Experiment Group (N = 51)	Control Group (N = 50)	Total (N = 101)	P
Age (years), mean (SD), (95% CI)	23.8 (SD = 1.0) (23.5–24.1)	24.1 (SD = 1.0) (23.8–24.4)	23.9 (SD = 1.0) (23.7–24.1)	.2052
Female, N (%)	27 (52.9)	24 (48.0)	51 (50.5)	.2441
Compression Depth (mm), mean (SD), (95% CI)	50.1 (SD = 4.8) (48.8–51.5)	47.5 (SD = 4.7) (46.1–48.8)	48.8 (SD = 4.9) (47.8–49.8)	**.0064**
Recoil Depth (mm), mean (SD), (95% CI)	49.2 (SD = 5.0) (47.8–50.6)	46.0 (SD = 4.7) (44.7–47.4)	47.6 (SD = 5.1) (46.6–48.6)	**.0014**
Compression Frequency (/min), mean (SD), (95% CI)	103.5 (SD = 10.6) (100.5–106.5)	97.8 (SD = 9.7) (95.1–100.6)	100.7 (SD = 10.5) (98.6–102.7)	**.0067**
Successful CC, N (%)	34 (66.7)	19 (38.0)	53 (52.5)	**.0041**

Table 1. Characteristics of the Subjects in Experiment and Control Groups
Abbreviation: CC, chest compressions.

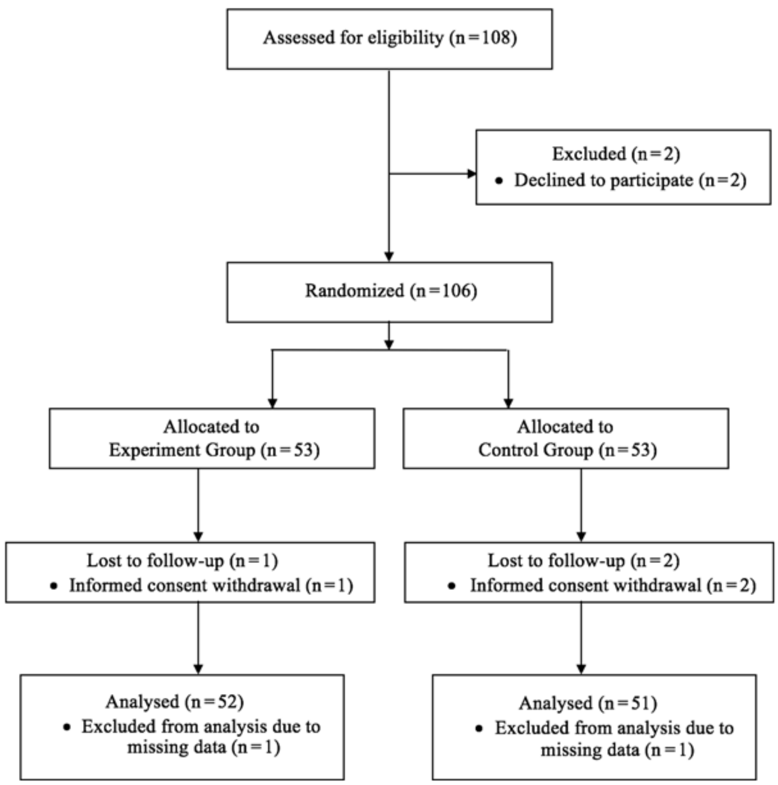

Figure 1. Flowchart of Subjects' Enrollment, Randomization, and Allocation in the Study.

The 2015 AHA Guidelines for CPR underline the importance of quality CCs for an efficient CPR and describes it as CCs with adequate depth, recoil, and rate.[5,24] Recent studies associated high-quality CCs with increased rates of survivals in cardiac arrests. Johansen, et al reported a five percent increase in survival from cardiac arrests with each one-millimeter compression depth improvement.[25] Vadeboncoeur, et al stated that every five-millimeter increase in compression depth increases the survival of cardiac arrest patients with an odds ratio of 1.29.[8] In an animal study, Babbs, et al reported that a 10mm decrease in compression depth resulted in 50% decrease in cardiac output.[26]

Physicians and other CPR providers struggle to achieve high-quality CCs.[2,7–10] Past studies have evaluated the factors that may have contributed in decreasing CC quality, such as providing CPR on a mattress. Mattresses compress during CPR. Cheng, et al and Guana, et al reported that the mean mattress compression depth is significantly lower with backboards when compared to only mattresses.[2,11] The increased mattress compression increases the vertical distance for the provider's hands to travel and increases the workload of the CPR provider. The increased workload and fatigue of the providers cause insufficient CCs.[9,14,17] In 2015, a mannequin study from Austria reported that the fatigue rates of

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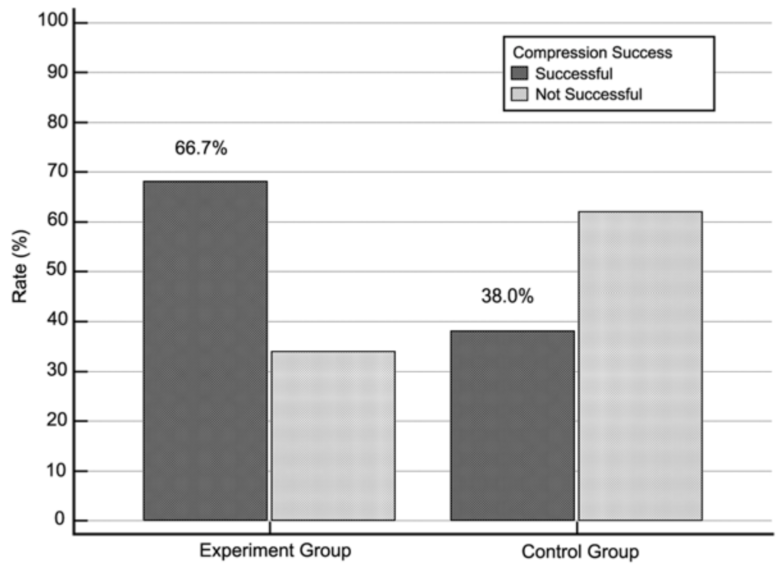

Figure 2. Chest Compression Success Rates.

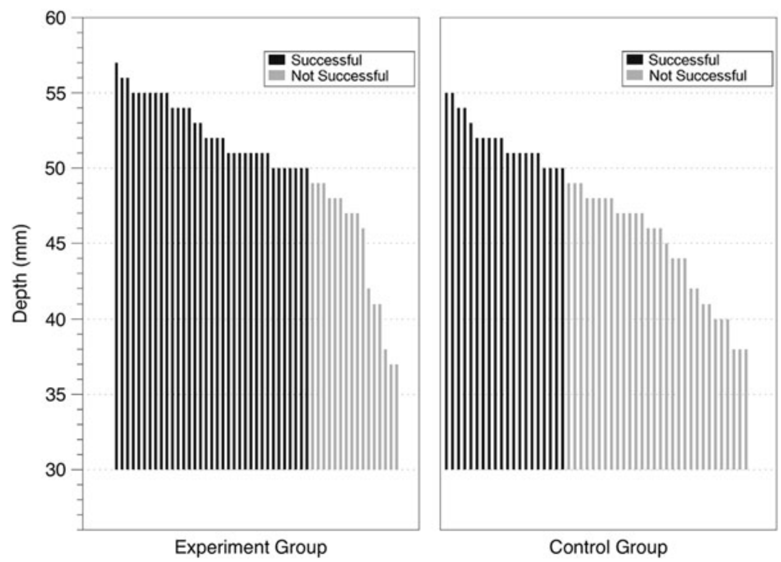

Figure 3. Chest Compression Depth and Success.

rescuers providing CCs with backboard were significantly lower than the ones without backboards (60% vs 70%; P <.001, respectively).[27] Given the importance of high-quality CCs, recent studies tried to develop methods that could reduce the compliance of the mattress and improve CC quality.

The use of mattress compression covers, vacuum pumps, and backboards are some of these methods.[28] In theory, using backboards should decrease the compliance of the mattress and reduce the workload of the provider, thus improve CC quality. However, there is a great debate in the literature whether the use of backboards during CPR can improve CC quality or not. The AHA Guidelines recommend an optional use of backboards during CPR due to this debate and the lack of reliable evidence.[17]

There are many past studies for and against the use of backboards during CPR. Putzer, et al reported that the mean CC depth (mm) and the mean CC rate (/min) significantly improved with backboard use when compared with only mattress use in their prospective, randomized, cross-over study with 24 subjects (50mm vs 51mm; 106 vs 115; P <.001, respectively).[27] Sato, et al reported significant improvement in mean CC depths with backboards (54 vs 49; P <.0001) and added that the difference in mean CC rates between backboard group and no-backboard group was insignificant.[15] In this study, the differences between the experiment group and the control group both in CC depth (50.1 vs 47.5; P = .006, respectively) and CC rate (100.5 vs 95.1; P = .007, respectively) were significant (Table 1). The results show that backboards improve mean

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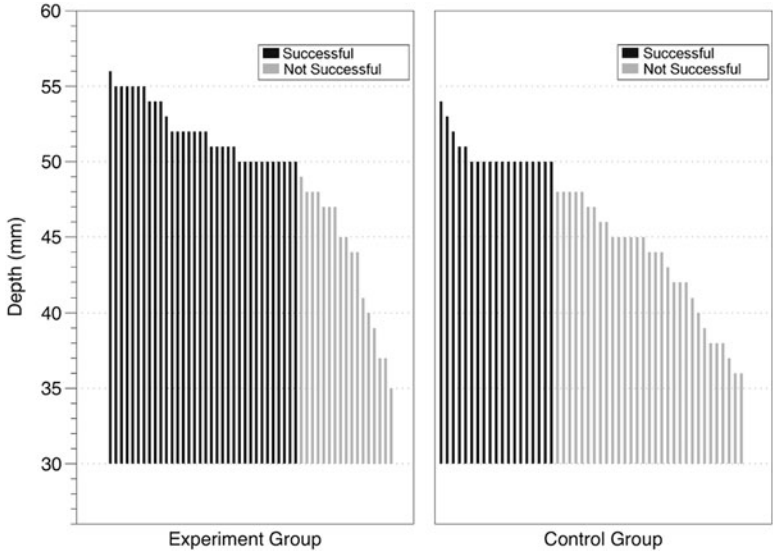

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Figure 4. Chest Compression Recoil Depth and Success.

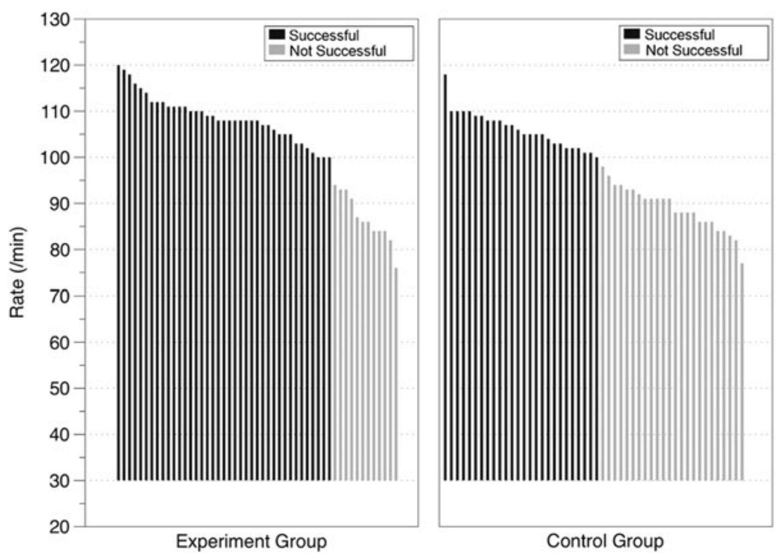

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Figure 5. Chest Compression Rate and Success.

CC depth and rate. The results in the Putzer, et al and the Sato, et al studies, in which both recommended the use of backboards during CPR, were close to this study's results. On the other hand, Fischer, et al stated against the use of backboards in their prospective study with 43 subjects since they found no significant improvement with backboards.[17] The mean CC depth values in this study are incompatible with the ones in the Fischer, et al study (41.2 vs 41.4, respectively). This difference between the two studies may have originated from the differences in mattress thicknesses and the number of subjects included in the studies. The mattress thickness in this study was 80mm, whereas in the Fischer, et al study, a 100mm thick mattress was used. The sample size of this study (n = 101) is also greater than the Fischer, et al (n = 43) study.

All of these recent studies, and many others, focused on the CC depths and rates. However, adequate chest wall recoil is also an essential component for high-quality CCs, and studies should evaluate recoil depth among CC depth and rate. All CPR providers should allow complete chest wall recoils. Complete chest wall recoils produce a negative pressure in thorax that increases venous return and blood flow to the cardiopulmonary system. Incomplete recoils decrease coronary perfusion, thus worsen resuscitation outcomes.[5] The results suggest that backboards not only increase the mean CC depth and rate, but also the recoil depths. The rate of successful CCs in the experiment group was significantly higher than the control group (66.7% vs 38.0%; P = .004; Table 1).

Limitations

There are several limitations to this study. First, only one mannequin was used, which may not accurately represent real clinical situations since patient sizes and weights may differ. Second, each subject was evaluated for one cycle (two minutes) of CCs, which may be insufficient to represent the real performances of the providers. Third, the interruptions between CC were not evaluated, since it was not among the goals, but it certainly influences the resuscitation outcomes.[5] Finally, the time loss in backboard placement was not observed, since this also was not among the goals of this study. However, many authors who stand against the use of backboards during CPR suggest that with backboards, unnecessary delays may occur.[17,22]

Conclusion

Backboard placement during CPR significantly increased successful CCs. The use of backboards increased CC quality by improving all three components (CC depth, CC recoil depth, and CC rate) of high-quality CCs as defined by the 2015 AHA Guidelines of CPR. Future prospective clinical trials, where CC interruptions and time loss in backboard placement are evaluated, are needed to make a prompt decision whether to use backboards during CPR or not.

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